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ABSTRACT

A study tested the hypothesis that the time it takes for information to be analyzed by the reader is sometimes delayed because concurrent comprehension processes are still occupied with analyzing previous information (the variable utilization time hypothesis). During fixations (when the eye rests during reading), visual information, at some point, is passed on to higher-level mental processors, such that the reader's comprehension of the text is furthered by the information. This is referred to as the time of utilization. Previous research showed that the time of utilization varies, occurring sometimes early, sometimes late, in the fixation. The method of determining the time of utilization used in previous experiments was combined with a manipulation of comprehension difficulty. The comprehension manipulation involved varying the distance between a pronoun and its referent, which has been shown to cause delayed processing effects. Subjects were college students or graduates with normal uncorrected vision, who read the text using a machine that recorded their eye movements during reading. The desired effects were not obtained in this experiment; thus the variable utilization time hypothesis could not be properly tested. Perhaps properties of the pronouns "he" and "she" made them easy to process regardless of distance from their referents, or discourse properties of the text involving focus change could have skewed the results. (Author/SKC)

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CENTER FOR THE STUDY OF READING

Technical Report No. 405

THE EFFECTS OF PRONOUN PROCESSING ON INFORMATION UTILIZATION DURING FIXATIONS IN READING

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The work reported here formed part of a doctoral dissertation submitted to the University of Illinois in 1985. The results were reported at the meeting of the Midwestern Psychological Association in May, 1986. Support came from National Institute of Education Contract 400-81-0030 to the Center for the Study of Reading. Thanks are due to Nancy Bryant, Pat Chrosniak, Pat Greenan, Luddy Harrison, Michael Reddix, Jerry Wilson, and Gary Wolverton for their assistance in programming and data collection. Thanks are also due to my committee, George McConkie, William Brewer, Charles Eriksen, Walter Schneider, and David Zola, for their help and suggestions. Requests for copies of this paper should be sent to Harry Blanchard, University of Massachusetts, Department of Psychology, Tobin Hall, Amherst, MA 01003.

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Abstract

During fixations, visual information, at some point, is passed on to higher-level processors, such that the reader's comprehension of the text is furthered by the information. This is referred to as the time of utilization. Previous research showed that the time of utilization varies, sometimes early, sometimes late, in the fixation. This experiment tested the hypothesis that the time of utilization is sometimes delayed because concurrent comprehension processes are still occupied with analyzing previous information (the *variable utilization time hypothesis*). The method of determining the time of utilization used in previous experiments (Blanchard, McConkie, Zola, & Wolverton, 1984) was combined with a manipulation of comprehension difficulty. The comprehension manipulation involved varying the distance between a pronoun and its referent, which Ehrlich and Rayner (1983) had shown to cause delayed processing effects. The desired effects were not obtained in this experiment; thus, the variable utilization time hypothesis could not be properly tested. Reasons for the failure to replicate Ehrlich and Rayner's (1983) effects are investigated. Also, some unpredicted results which support the variable utilization time hypothesis are discussed.

The Effects of Pronoun Processing on

Information Utilization During Fixations in Reading

In reading, the eye makes a series of quick movements (saccades) from one point in the text to another. Between these movements are fixations, during which the useful visual information for reading is acquired. During the entire period of fixation, visual information is made available to the brain. At some point, visual information is passed on to higher-level processors, that is to say, the visual information is used to further comprehension of the text. This point in time, when visual information is used by comprehension processes, is the focus of this paper. This point in time is called the *utilization* of visual information (and is distinguished from simple *registration*: transmission of information to the visual cortex and perhaps some early pattern recognition; see McConkie, 1983).

Earlier experiments (Blanchard, 1986; Blanchard, McConkie, Zola, & Wolverton, 1984) have shown that visual information is not utilized at the same point in every fixation. Visual information is sometimes utilized early in a fixation and sometimes late. In these experiments, subjects read from a computer screen while their eye movements were monitored. A single letter (the critical letter) was changed partway through each fixation. For each text the subjects read, two critical letters resided in two critical words which both fit and made sense in the text, e.g., *The underground caverns were meant to house hidden (tombs, bombs), but then the construction was stopped because of lack of funds.* On fixations near the critical word, the word initially present, *tombs*, was changed to its alternative, *bombs*, after some delay (50-120 ms). During saccades, the initially presented word was replaced. In addition, a mask was presented for 30 ms in order to eliminate localized apparent movement caused by changing the critical letter.

The result was that subjects frequently reported seeing only one of the critical words. They sometimes reported the first word, sometimes the second, and sometimes both words. If information always had to be passed on to higher comprehension processes (utilized) immediately after registration, then subjects should always consistently report the first word in these experiments. Clearly, information does not always have to be utilized right after the completion of early visual processing. Sometimes there is a delay, where visual information remains available, but is not utilized until much later in the fixation.

The corollary of this conclusion is that something other than just the completion of registration determines when information is utilized by comprehension processes. Blanchard, et al. (1984) introduced this as the *variable utilization time hypothesis*. They claimed that the time of utilization varies, sometimes early and sometimes late in the fixation. The reason why utilization is sometimes delayed until after the beginning of the fixation is that the comprehension processes are not ready to accept new visual information; they are occupied with analyzing previous information. Only when the comprehension processes are in a state where comprehension can be furthered by new visual information does utilization occur. In other words, the time of utilization is determined by the current need of ongoing comprehension processing.

This experiment explicitly tests the variable utilization time hypothesis. The same changing-letter procedure used by Blanchard, et al. (1984) is used here and combined with a manipulation which is known to affect comprehension difficulty. The goal is to use a manipulation of comprehension processes to cause selective changes in the probability of reporting the first and second of the changing words.

The comprehension process manipulation chosen was the difficulty of the semantic integration of a pronoun preceding the critical word. The referent of the pronoun appeared either immediately before the pronoun (*near* condition) or 1-3 sentences prior to the pronoun (*far* condition, see Table 1). This manipulation was used by Ehrlich (1983) and Ehrlich and Rayner (1983) in eye movement experiments which did not involve any text changes on the screen. They found that, in the near

condition, semantic integration of the pronoun was completed on the fixation on which the pronoun was visually acquired, and, in the far condition, semantic integration was not completed until 1-2 fixations after the pronoun. This was indicated by the pattern of fixation durations in the vicinity of the pronoun.

[Insert Table 1 about here.]

The delayed processing effects suggest that there should be spillover of pronoun processing on the fixation following the fixation on which pronoun was acquired, where, in this study, the critical word is located. The predictions from the variable utilization time hypothesis are as follows. In the near condition, pronoun assignment is easy. Pronoun processing should usually be completed on the pronoun encoding fixation. When the eye is on the critical word location, information should be utilized early during the fixation, because comprehension processes are ready to accept new visual input right away. Hence, the first word should be reported more often. In the far condition, pronoun assignment is more difficult than in the near condition, and pronoun processing should extend beyond the pronoun encoding fixation (as found by Ehrlich & Rayner, 1983). When the eye is on the critical word location, comprehension processes may not be ready to integrate new information until pronoun processing is completed. Thus, utilization during the fixation on the changing word should be more likely to occur late in the fixation; hence, the second word should be reported more often.

Method

Subjects

All subjects were either college students or college graduates, had normal uncorrected vision, and were native speakers of English. They had not previously participated in an experiment involving display changes contingent on eye movements.

Apparatus

The text was displayed one line at a time and in upper and lower case letters on a DEC VT-11 display unit. The subjects were 68 cm from the display screen, so that 1^{o} of visual angle encompassed four character positions. The subjects read the multiline passages by pressing a button each time they needed to go forward to a new line. While subjects were reading, their eye movements were recorded every millisecond with an SRI Dual Purkinje Image Eyetracker in conjunction with a DEC PDP-11/40 minicomputer. Head movements were reduced by using a headrest and bitebar.

Materials

Each 3-5 sentence text had two different versions, which were different in meaning, but visually different by only one letter. This letter was located in a five-letter critical word (in any of the five letter positions), e.g., *plaid* and *plain*. In addition, the texts were written so as to contain the Ehrlich and Rayner (1983) pronoun-referent distance manipulation. Each critical word immediately followed a pronoun. The pronoun was the first word in a sentence. In the *near condition*, the referent immediately precedes the pronoun; it was the last word of the preceding sentence. In the *far condition*, the referent was 1-3 sentences before the pronoun. An example is shown in Table 1, and a complete listing appears in Blanchard (1985-86).

Procedure

On every fixation subjects made reading the texts, the text was momentarily masked for 30 ms at some time during the fixation. (The mask consisted of two overprinted lines of upper case Xs and Os overprinted at each character position, with one line extending below the text line.) The time between the beginning of a fixation and the onset of the mask was either 50 or 100 ms. Thus, each

fixation is divided into three time periods: the time before the mask (either 50 or 100 ms), mask time (always 30 ms), and the time after the mask (variable, depending on the fixation duration).

In the experimental condition, the letter which distinguished the two alternate versions of the text was changed during certain selected fixations, while in the control condition, this critical letter was not changed. In other words, in the control condition, the line of text which reappeared after the mask was identical to the line of text which appeared before the mask. Whereas, in the experimental condition, the line reappearing after the mask was the alternate version of the text (different by one letter from the text preceding the mask).

The letter would change in the critical word only if (a) at least one fixation had previously occurred within 12 character positions of the left end of the line, (b) the fixation was located within a region extending 11 character positions to the left and right of the first letter of the critical word, and (c) since initially entering this region the eyes did not pass out of it to the right (i.e., no changes on regressions aimed back into the region from outside the region).

In addition, the distance between a pronoun and its referent in the texts was manipulated by preparing two contrasting versions of each text, as explained earlier. Assignment of texts to conditions was random and counterbalanced, and presentation order of critical words in the fixation was counterbalanced across subjects. Subjects were informed about the mask and the changing letters, but not about the pronoun-referent distance manipulation.

A recognition test procedure was used to determine which critical word or words subjects had read. After reading each text, four test words appeared individually, one after the other. For each word, the subject identified whether it had appeared in the immediately preceding text by pressing a "yes" or "no" button. Two of the test words were the critical words. The other two test words also differed by one letter, although one of these words did not ever appear in the text. Presentation order of test words was randomized.

Results and Discussion

To provide a test of the variable utilization time hypothesis, it is necessary to determine whether this experiment successfully replicated the same pronoun processing effects as found by Ehrlich (1983) and Ehrlich and Rayner (1983). The algorithm used by Ehrlich and Rayner (1983, pp. 80-81) was used here to select four fixation sets: (1) the fixation prior to encoding the pronoun, (2) the fixation on which the pronoun was encoded, (3) the fixation following encoding, and (4) the fixation two after encoding. The algorithm defined the pronoun encoding fixation as the fixation closest to the pronoun which fell within a region extending six character positions to the left of the first letter of the pronoun and one character position to the right of the final letter of the pronoun. In the current experiment, fixations following encoding are likely to fall on the critical changing word. The data from the control condition of the present experiment were compared to the Ehrlich and Rayner (1983) data (the near and far conditions of their Experiment 2, from Table 3, p. 82, are plotted in Figure 1).

[Insert Figure 1 about here.]

Figure 2 presents the mean fixation durations for the four fixation sets defined by the above algorithm. The pattern of effects is different from Ehrlich and Rayner's (1983) results. In particular, there was no increase in the duration of fixations following encoding of the pronoun in the far condition. This is the crucial effect which Ehrlich and Rayner (1983) attributed to delayed processing of the pronoun, and which is crucial to producing the effects predicted in this experiment. In a repeated measures analysis of variance, the main effects of Pronoun-Referent Distance, $F(1,15) = 4.80$, $p = .05$, and Serial Order of Fixation, $F(3,45) = 9.36$, $p \sim 0$, were significant. The interaction was

not significant. This experiment has failed to replicate the delayed processing effects found by Ehrlich and Rayner (1983).

[Insert Figure 2 about here.]

The failure could be due to some effect of the mid-fixation masking on language processing. To examine this possibility, a second experiment was conducted with the same texts, but with no masking and no changing letters. Eighteen subjects, separate from those used in the main experiment, read the texts and performed the recognition tests with the same test words as in the main experiment. None of these subjects had previously participated in an experiment with display changes or with texts similar to these texts. The effect of pronoun-referent distance on mean fixation durations was examined in the same way as in the main experiment and are presented in Figure 3. There is an increase in mean fixation duration in the far condition relative to the near condition on the fixation one after pronoun encoding, but not on the fixation two after pronoun encoding. The pattern of fixation duration effects does not match the results of Ehrlich and Rayner (1983), and are somewhat similar to the pattern in the control condition of the main experiment. The main effect of Pronoun-Referent Distance was not significant but Serial Order of Fixation was significant, $F(3,51) = 16.10$, $p < 0$, as was the interaction, $F(3,50) = 5.40$, $p = .003$. In sum, the mask presented during each fixation in the main experiment cannot account for the difference in results between that experiment and the original Ehrlich and Rayner (1983) experiments.

[Insert Figure 3 about here.]

The most likely explanation for the different results of these two experiments lies with some linguistic property of the texts. One possibility is that the current experiment used other pronouns in addition to the pronouns *he* and *she*. At least some of these other pronouns could have had different effects on ongoing language processes. To examine this possibility, the effect of pronoun-referent distance on fixation durations (in the main experiment) was analyzed for only those texts which used *he* and *she* as the critical pronouns. Figure 4 shows there is an increase in mean fixation duration for the first fixations after pronoun encoding, but no increase for fixations two after encoding. This effect in the far distance condition is small and does not match the pattern found by Ehrlich and Rayner (1983). Furthermore, neither the main effects of Distance and Serial Order of Fixation nor the interaction were significant. Thus, the difference in pronouns cannot be the major explanation for the difference between this experiment and Ehrlich and Rayner (1983).

[Insert Figure 4 about here.]

The difference between the current texts and those of Ehrlich and Rayner (1983) may be in the discourse structure of the texts in the far condition. Ehrlich and Rayner give an example of one of their texts in the far condition (from their Table 1, p. 80, here the pronoun and referent are italicized):

> A group of people who shared an interest in photography had recently started writing a newsletter of their activities. *Mark* wrote most of the copy but the other members did a lot of work as well. In fact, in one room Cathy was mailing a copy of the paper to Susan. *He* was very involved in photography and spent every weekend taking pictures.

Between the pronoun *he* and its referent *Mark*, the focus or topic is changed from Mark to Cathy and Susan. The reader has no expectation that the discourse will return to Mark, but, at the pronoun *he*, it does.

Compare the far version of a text from this experiment:

> Unlike most rock stars, noisy crowds of screaming teens irritate *Ted*. This leads to behavior that is considered unusual for a rock star. *He* (shuns, stuns) his fans by simply walking out of a room without talking or waving to anyone.

Here, the text intervening between the pronoun and its referent does not change focus, and does lead the reader to expect more information about Ted further in the text. Most of the texts in this experiment are constructed similarly, as the result of an effort to keep the near and far texts as similar as possible.

The significance of this difference depends on what kind of linguistic structure is actually responsible for increased processing time required by a pronoun. It may simply be the number of words between a pronoun and its referent. However, it may be a sort of "mental distance" which is important: The referent to a pronoun becomes harder to compute as that referent is further in the background of the current mental representation of the text. This would be correlated with physical distance, but physical distance would not be sufficient to move a referent out of the current focus of the discourse. Similar arguments are made by Kantor (1977-78), Carroll and Slowiaczek (in press), and Clifton and Ferreira (in press).

Given that the materials used in this experiment failed to reproduce the delayed processing effects in the far condition found by Ehrlich and Rayner (1983), this experiment does not provide an adequate test of the predictions of the variable utilization time hypothesis, as presented earlier.[1]

However, a post hoc interpretation of this study is possible if the above argument about discourse focus and pronoun processing is correct. If it is, then the far condition of the current study is essentially the same as the near condition: Pronoun processing may have been facilitated in both the near and far conditions. According to the original predictions, easy pronoun processing allows early utilization of the changing word. Therefore, utilization may tend to occur early on fixations in both the near and far conditions. However, to test this, some neutral comparison is needed. The best available comparison is the pattern observed in Blanchard, et al. (1984). Consistent with this new prediction, the word present first in the fixations was reported more often than the second, unlike Blanchard, et al.'s (1984) pattern, in which the probability of reporting the first or second word was nearly equal. Table 2 presents the percentage of single word reports which were reports of the first and second words in this experiment and in Blanchard, et al. (1984). Only the current experiment shows a significant difference by a chi-square test on the frequencies for first and second word reported ($X^2(1, N = 16) = 17.63, p < .001$).

[Insert Table 2 about here.]

Firm conclusions cannot be made from this experiment, because the desired pronoun processing effects were not produced. However, there is some suggestion by post hoc analysis that the variable utilization time hypothesis is supported. Further research is needed to confirm this. Another implication of this study is that the difficulty of semantic integration of a pronoun is a function not of the distance between the pronoun and its referent, but rather of discourse characteristics of the text, namely whether the referent of the pronoun has been kept in the foreground or background of the ongoing mental representation of the text.

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Footnote

[1]The reports made on the recognition test and the effects of the changing letter on the durations of fixations on the critical word were analyzed, in order to compare the results of this experiment to earlier changing-letter experiments. These results are reported in Blanchard (1985-86).

Table 1

Sample Text in Two Pronoun-Referent Distance Conditions

Near Condition

This was clearly another act of the Hillsdale Strangler, which was why Farnsworth was brought in on the case. Detective Harold Farnsworth looked at the murdered *woman*. *Her* (plaid, plain) blouse was splattered with blood. But an insignia on the blouse linked the woman to a Satanic cult.

Far Condition

Detective Harold Farnsworth looked at the murdered *woman*. This was clearly another act of the Hillsdale Strangler, which was why Farnsworth was brought in on the case. *Her* (plain, plaid) blouse was splattered with blood. But an insignia on the blouse linked the woman to a Satanic cult.

Table 2

Percentage of Single Word Reports in Two Experiments

	Word Reported	
Experiment	First	Second
Blanchard et al. (1984)	45	55
This Experiment	64	36

Figure Captions

Figure 1. Mean fixation durations for fixations at various locations with respect to the pronoun in the near and far pronoun-referent distances of Ehrlich and Rayner's (1983) Experiment 2.

Figure 2. Mean durations for fixations at four locations with respect to the pronoun in the near and far pronoun-referent distances of the control condition.

Figure 3. Mean durations for fixations at four locations with respect to the pronoun in the near and far pronoun-referent distances of a second experiment in which there was no masking and no changing letters.

Figure 4. Mean durations for fixations at four locations with respect to the pronoun in the near and far pronoun-referent distances of the control condition. The data here come only from texts in which the pronoun was either *he* or *she*.

Figure 1

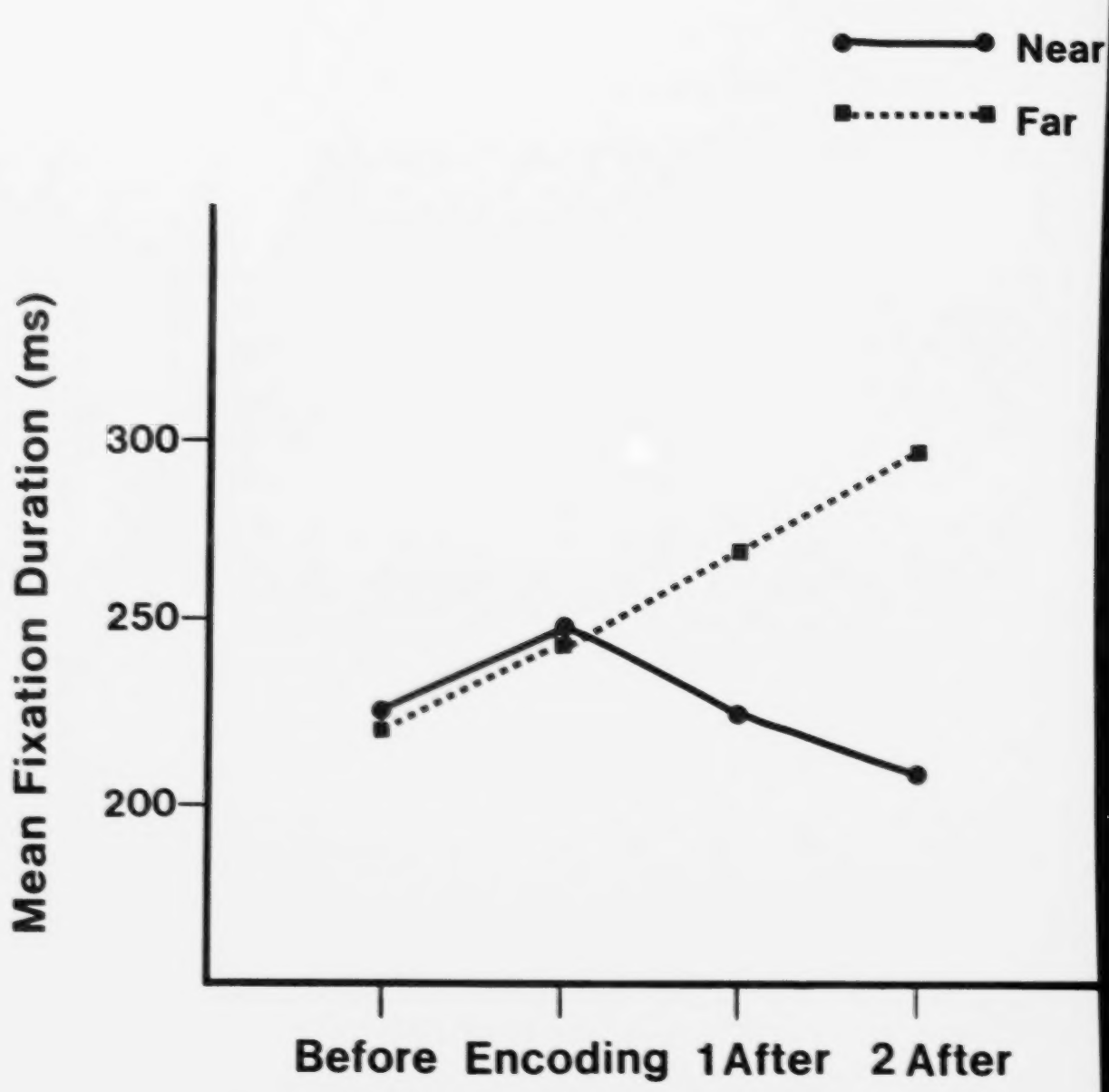
Near
Far
Mean Fixation Duration (ms)
300
250
200
Before Encoding
1 After
2 After

Figure 2

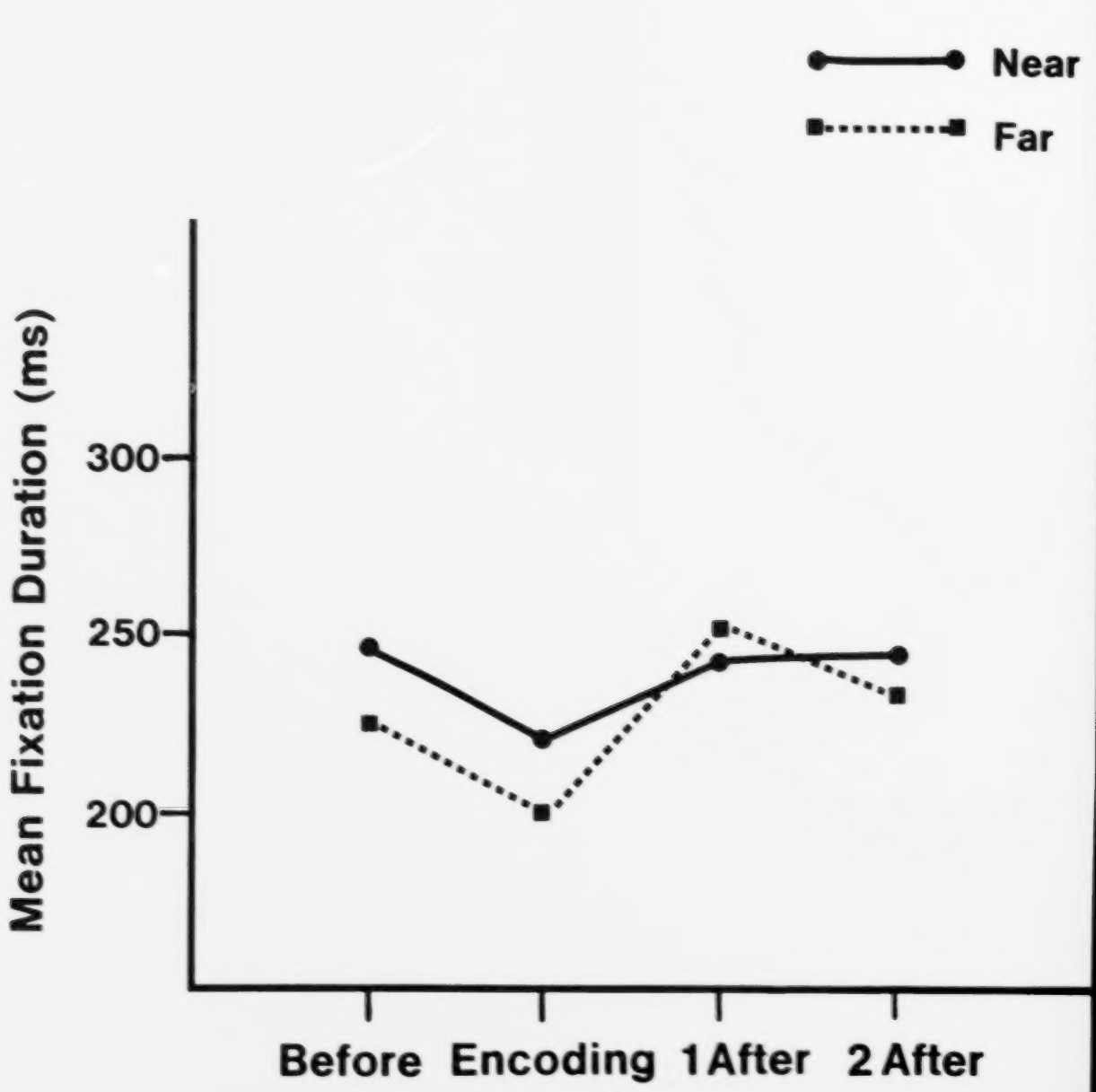
Near
Far
Mean Fixation Duration (ms)
300
250
200
Before Encoding
1 After
2 After

Figure 3

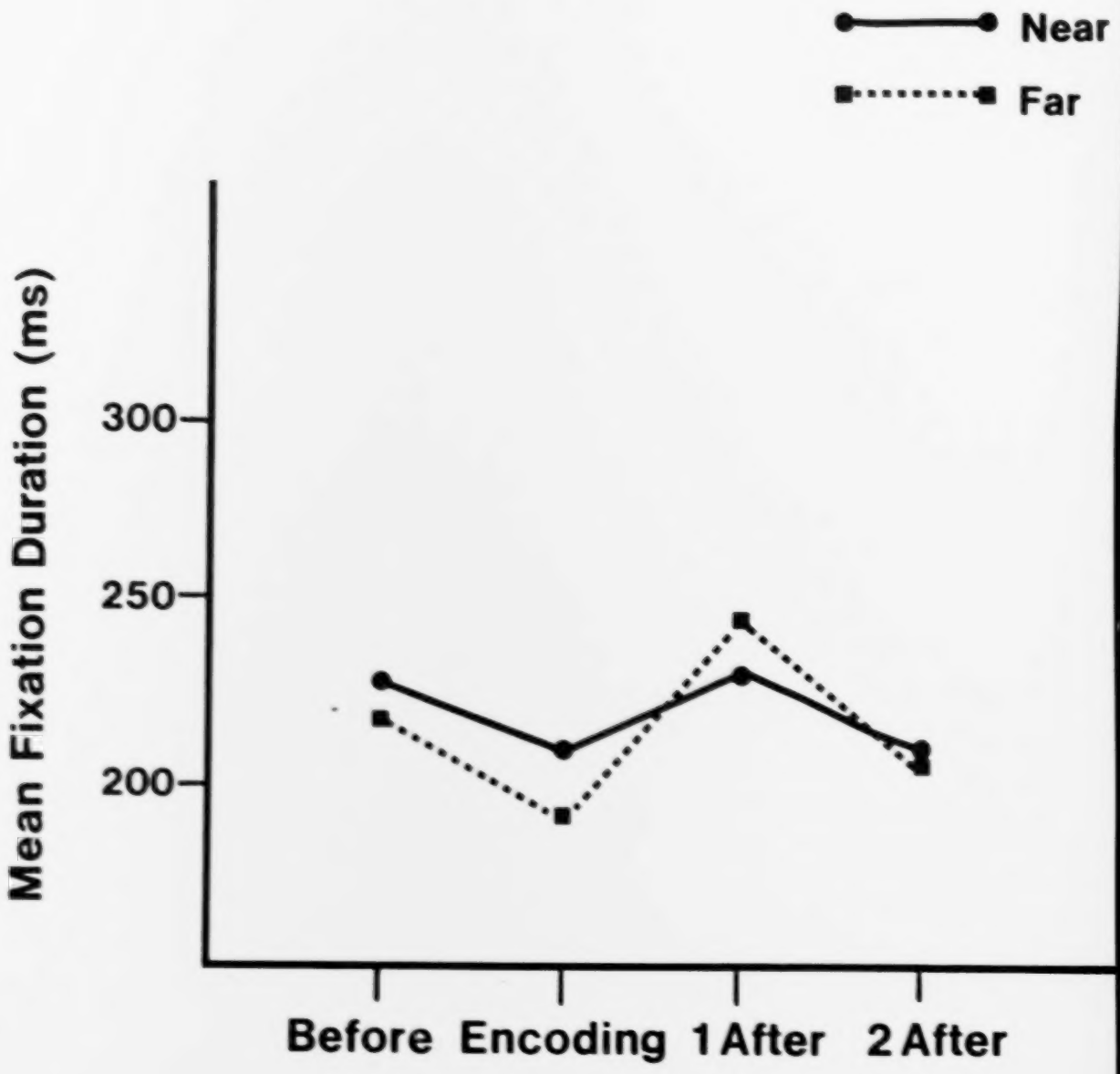
Near
Far
Mean Fixation Duration (ms)
300
250
200
Before Encoding
1 After
2 After

Figure 4

Near
Far
Mean Fixation Duration (ms)
300
250
200
Before Encoding
1After
2After